Mathematical modelling

Pollution in the Great Lakes

Bob Thomann
I was in the Public Health Service as a Commissioned Officer at the time, and I remember writing some of these equations down and one of the other mad scientists in the Public Health Service said: “You know that’s a model”, and that was the first time I heard that word. And I said: “What’s a model?” He says: “Well, it’s a representation of the Connecticut River”, and I said: “Well that’s interesting”. And it was a defining moment, you know, one of those defining moments. I remember him saying: “That’s a model”, and I’d never heard that word before, even though the equations had been around at that point for maybe fifty or sixty years.

Susan Rae
Bob Thomann was one of the founders of water quality modelling in the United States. And modelling – mathematical modelling – has provided one of the biggest success stories in pollution control over the past thirty years: the story of the Great Lakes.

The Great Lakes of North America are five large freshwater inland seas on the border between Canada and the USA.

Biggest of all, and further west, is Lake Superior.

South of Superior, and entirely within the USA, is Lake Michigan.

Water from both Superior and Michigan flows into Lake Huron.

The flow then runs through the Detroit River into Lake Erie, the smallest of the Lakes.

Finally, it passes over Niagara Falls, through Lake Ontario, and then out into the St. Lawrence River and the Atlantic.

The lakes now are very much cleaner than they were in the fifties and sixties, and their traditional use for recreation is regaining its popularity. Lakeside resorts are centres for fishing, sailing and other water-based sport. And the lakes contain fresh water, so they’re used to provide drinking water for a large part of the North American population.

Much of the political impetus for cleaning up the lakes came from the International Water Quality Agreement signed in 1972 by Richard Nixon and Pierre Trudeau.

In the United States responsibility for monitoring water quality, and advising on changes, was given to the Environmental Protection Agency. And much of the modelling work was carried out at their Large Lakes Research Lab in Grosse Ile, an island in the Detroit River at the north-west tip of Lake Erie.

Bill Richardson is former station chief at the Lab

Bill Richardson
I was accepted in the Public Health Service, and through the course of my discussions with these fellow students, I became aware of, you know, the tremendous pollution problem that was going on in this country.

Of course we’d discuss that in classes. It was on national news, Kennedy had just been elected President and he was making quite an issue out of this.

The state of Michigan was going through turmoil with the pollution problems in the Great Lakes.

Actually the Great Lakes clean-up and whole effort on water pollution control focused on Lake Erie and the Detroit River in the late fifties, early sixties, when there were tremendous oil slicks coming down the river from the industries, from the auto plants and the steel industry.

Susan Rae
Industrial plants like these produce the most obvious forms of pollution. This is River Rouge, just south of metropolitan Detroit, and one of the centres of heavy industry in the state of Michigan. Even now some of the waste products from these factories are washed down the River Rouge, out into the Detroit River and then into Lake Erie.

But pollution doesn't come only from industry. Much of it is a result of ordinary, everyday life.

Bob Thomann
We could start with bacterial pollution which is a direct result of human sewage. From sewers, combined sewer overflows, which is a combination of rainfall and sewerage, and from treatment plants.

Then sewage also has various kinds of organic material in it that is not of a toxic chemical point of view, but organic waste that can use up oxygen when discharged to a stream or a lake. And that oxygen then impacts…the loss of oxygen impacts the aquatic ecosystem.

Then of the problem of nutrient enrichment from both treatment plants, from humans, as obviously we discharge nitrogen and phosphorous in our waste, and from agricultural run off.

So bacteriological pollution, organic material that contributes to lowering of oxygen, nutrient enrichment is another area. And then finally the toxic chemicals, heavy metals: zinc, mercury, copper, cadmium, which have been around since…since the very beginning, and the newer chemicals, the organic chemicals synthesised by and large since the Second World War, of which there are hundreds of thousands. So in a very broad category those are the major pollution problems.

Susan Rae
Some of these newer chemicals are called PCBs: poly-chlorinated biphenyls. There are nearly two hundred different kinds of PCBs, and they've been used in many different manufacturing processes.

Bill Richardson
The problem that became more evident in the late seventies, eighties was that of toxic substances. It was determined that PCBs was a major problem, affecting the possible risks for human health was determined that children of mothers who ate a lot of Great Lakes fish, the infants were displaying certain abnormalities and characteristics that were very disturbing to people. So it was determined to actually ban PCBs even before we modelled it. The problem with PCBs is that a lot of it was produced since 1929, so it was all out in the environment. In inks, carbonless paper, in florescent light fixtures, industrial oils. Even though we banned the use…the manufacture of PCBs in the country, this….millions and millions of pounds of this were distributed in the environment.

Susan Rae
But despite the apparent size of the problem, the environment can often be forgiving. Lake Michigan alone contains five million, million cubic metres of water, enough to swamp modest amounts of pollution. And the holiday resorts in the north of the lake are four hundred kilometres away from the polluting factories of the south.

But still, the pollution has had to go somewhere. It could decay naturally into harmless substances. It could be washed out to sea by the flow of water. Or it could accumulate.

And if it does accumulate, how much of it will there be next year? Or in five years? Or ten years?

And what will happen if the input of pollution is restricted? Or if it's stopped altogether?

The only way to find out is by modelling.

Bob Thomann
Why modelling and what's the options? The options are to guess at what the effectiveness of certain control actions are, and guessing, maybe my guess, maybe as good as your guess, and that's when controversy arises. So that to the degree to which a model provides at least some objective assessment of the situation, and is credible in the sense that it reproduces observed information, then we might agree that yes, this kind of technique is a useful way to make assessments of the impacts of various environmental control actions.

But without a model we'd always be flying blind, we'd always be guessing, we'd say: "Well maybe on the one hand this, on the other hand that". And then I mean it's also sometimes argued: "Why don't we just go out and measure everything we need to measure, and on the basis of the measurements make an assessment of what the impacts will be?" Well that's fine up to a certain point. Most of the time the decisions we're asked to make are to extend the environmental controls beyond what we've already observed, so the question is always a forecasting question, a projection question which we can't measure.

So measurements by themselves will never answer the question of what are the impacts of different kinds of environmental control actions. So hence modelling enters the door.